

PROTON DECAY IN SO(10) SUPERSYMMETRIC GRAND UNIFIED THEORIES ^{*†}

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We calculate the proton lifetime in an SO(10) supersymmetric grand unified theory [SUSY GUT] with U(2) family symmetry. This model fits the low energy data, including the recent data for neutrino oscillations. We discuss the predictions of this model for the proton lifetime in light of recent SuperKamiokande results which significantly constrain the SUSY parameter space of the model.

Some of the nicest features of SUSY GUTs are gauge and Yukawa coupling unification and also the interesting prediction of proton decay. Interesting because this prediction has a chance to be observed or excluded by SuperKamiokande and Soudan II experiments. In SUSY GUTs with an additional family symmetry, acting horizontally between generations, the hierarchy between generations can be generated by sequential spontaneous breaking of this symmetry. Several predictive models of this type were constructed. In this talk we focus on the models with a $U(2)$ or, its discrete subgroup, D_3 family symmetry.¹ These models fit the low energy data quite well including the recent data for neutrino oscillations. In what follows we calculate the proton lifetime in these models: we review the origin of proton decay in SUSY GUTs, discuss parameters which are crucial for the calculation of the proton lifetime and compare results with recent experimental limits. For a more detailed discussion see Ref.² and references therein.

The dominant contribution to proton decay in SUSY GUTs involves dimension five baryon and lepton number violating operators. These operators result from the exchange of color triplet Higgsinos which below the GUT scale are integrated out resulting in suppression by one power of the effective color triplet mass \tilde{M}_t . The effective four-fermion baryon and lepton number violating operators are obtained by dressing these dimension five operators by gluino, chargino and neutralino exchanges.

^{*}This talk is based on work done in collaboration with A. Mafi and S. Raby.

[†]Ohio state university preprint OHSTPY-HEP-T-00-018.

The dominant decay mode of the proton is $p \rightarrow K^+ \bar{\nu}$ and the amplitude for this process can be written in the following way:

$$T(p \rightarrow K^+ \bar{\nu}) \simeq (FF) \frac{M_{1/2}}{m_0^2} \frac{1}{\tilde{M}_t} \beta_{lat}, \quad (1)$$

where (FF) is the flavor factor depending on Yukawa and gauge couplings (it is fixed once we fit the low energy data), $M_{1/2}/m_0^2$ is a good approximation to a gaugino–scalar–scalar loop factor for $M_{1/2} \ll m_0$, \tilde{M}_t is an effective color triplet mass and β_{lat} is a chiral Lagrangian factor. In what follows we discuss the allowed regions of these parameters and use them to find the upper bound on the proton lifetime. In this talk we focus on the large $\tan\beta$ regime (discussion concerning the low $\tan\beta$ regime can be found in Ref.²).

The chiral Lagrangian factor β_{lat} appears in the calculation of the matrix element of the four–fermion operator between a proton and lepton + meson final state. The recent lattice calculation gives $\beta_{lat} = 0.015 \text{ GeV}^3$ with a very small statistical uncertainty (± 1 in the last digit).³ We use this central value in our calculation. However the systematic uncertainties connected with the chiral Lagrangian approach and the quenched approximation may be significant.

To suppress proton decay the effective color triplet mass \tilde{M}_t has to be very large. It is a free parameter constrained only by requiring perturbative threshold corrections to gauge coupling unification. If we define the GUT scale M_G and the unified gauge coupling at the point where α_1 and α_2 meet: $\alpha_G(M_G) = \alpha_1(M_G) = \alpha_2(M_G)$ then we typically need a correction to α_3 at the GUT scale (given by $\epsilon_3 = (\alpha_3(M_G) - \alpha_G(M_G))/\alpha_G(M_G)$) about -2% to -4% to obtain $\alpha_3(M_Z) = 0.119$. The one loop threshold correction from the Higgs sector ($5 + \bar{5}$) only is given by⁴

$$\epsilon_3 (Higgs) = \frac{3\alpha_G}{5\pi} \log \left(\frac{\tilde{M}_t}{M_G} \right). \quad (2)$$

If the maximum allowed threshold correction from the rest of the GUT sector is -10% then $\epsilon_3 (Higgs)$ can be at most 6% which through Eq. (2) translates into the upper bound for the effective color triplet mass $\tilde{M}_t = 8 \times 10^{19} \text{ GeV}$.

As can be seen from Eq. (1) in order to suppress proton decay, gaugino masses should be as small as possible. To be consistent with present experimental bounds on gaugino masses we take the universal gaugino mass at the GUT scale to be $M_{1/2} = 175 \text{ GeV}$.

On the other hand squarks and sleptons should be as heavy as possible. However in order for SUSY to solve the gauge hierarchy problem squark and slepton masses are expected to be near the weak scale. Otherwise fine tuning is necessary to obtain $M_Z \sim m_{Higgs} \ll \Lambda_{SUSY}$. Thus this naturalness criteria places an upper bound on squark and slepton masses. In fact it affects mostly squarks and sleptons of the third generation since the first two generations couple weakly to the Higgs boson. Furthermore due to renormalization group running the third generation scalars are naturally lighter than the scalars of the first two generations. Thus if we demand

that the scalars of the third generations are lighter than 1 TeV we can take the universal scalar mass at the GUT scale to be $m_0 = 3 TeV$.

With all these ingredients we calculate the theoretical upper bound on the proton lifetime:

$$\tau(p \rightarrow K^+ \bar{\nu}) = 4.7 \times 10^{33} \text{ years.}$$

This should be compared with the latest SuperKamiokande 90% CL bounds on proton decay based on 61-ktonyear exposure:⁵

$$\tau_{exp}(p \rightarrow K^+ \bar{\nu}) > 1.9 \times 10^{33} \text{ years.}$$

From this comparison several general conclusions can be drawn. SuperKamiokande bounds on the proton lifetime severely constrain $SO(10)$ SUSY GUTs. To stay above the experimental limit on proton decay gaugino masses have to be near the allowed experimental lower bounds while squark and slepton masses have to be near the upper bounds allowed by naturalness. Furthermore we have to allow a 6% threshold correction at the GUT scale coming from the Higgs sector. Thus the theoretical upper bound on the proton lifetime we present is to be considered as very conservative. Nevertheless it is barely consistent with the experimental limit.

Acknowledgements

I would like to thank my collaborators A. Mafi and S. Raby and organizers of the DPF2000. This work was supported in part by DOE grant DOE/ER/01545-787.

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